

Algorithmic Undecidability Does Not Imply Non-Algorithmic Physics A Constructive Refutation of Faizal et al. (arXiv:2507.22950)

SciMind 2.0¹

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A recent proposal by Faizal, Krauss, Shabir, and Marino (arXiv:2507.22950) argues that the existence of undecidable phenomena in physics (based on Gödel’s incompleteness and Tarski’s undefinability) necessitates that the fundamental laws of the universe be non-algorithmic, thereby ruling out the simulation hypothesis. We present a constructive refutation of this thesis. By analyzing a rigorous “Toy Universe” governed by Rule 110 cellular automata, we demonstrate a system that is (1) fundamentally algorithmic and strictly deterministic, yet (2) possesses undecidable global properties and Gödelian incompleteness. We show that Faizal et al. commit a category error by conflating *simulation* (step-by-step state evolution) with *prediction* (infinite-time derivation). We further argue that the inability of a system to define its own truth predicate (Tarski) is a standard feature of formal systems and requires no non-algorithmic “meta-laws” to resolve physically. Thus, undecidability is a predictable consequence of algorithmic complexity, not evidence of non-algorithmic ontology.

INTRODUCTION

The search for a Theory of Everything (TOE) often presumes that the universe operates according to a consistent set of mathematical rules. In their recent work, Faizal et al. [1] challenge the view that such a theory can be purely algorithmic. Their argument relies on a chain of logical inferences stemming from mathematical logic:

1. **Gödel Incompleteness:** Any sufficiently strong arithmetic system contains true but unprovable statements.
2. **Tarski’s Undefinability:** Truth cannot be defined within the system itself.
3. **Physical Undecidability:** Phenomena such as spectral gaps and renormalization group flows can be formally undecidable.

From this, they conclude that a purely algorithmic TOE ($\mathcal{F}_{QG}$) is impossible, as it cannot account for these truths. They propose a “Meta-Theory of Everything” ($\mathcal{M}_{ToE}$) relying on non-algorithmic resources and conclude that the universe cannot be a simulation.

In this paper, we refute this conclusion. We accept the premises (1-3) but reject the inference. Using a constructive proof based on Turing-complete cellular automata, we show that undecidability is an expected property of algorithmic systems, not a contradiction of them.

THE CATEGORY ERROR: SIMULATION VS. PREDICTION

The central flaw in the argument of Faizal et al. is the conflation of two distinct computational concepts:

- **Simulability:** The ability to compute the state $S(t+1)$ given state $S(t)$ using a finite algorithm.

- **Predictability (Decidability):** The ability to determine, for an arbitrary property P and infinite time, whether P will ever occur.

Faizal et al. argue that because certain outcomes are undecidable (unpredictable), the mechanism generating them cannot be algorithmic. This is false.

Consider the Halting Problem. A Universal Turing Machine (UTM) is fully algorithmic. Its transition function is a finite table. However, the question “Will this UTM halt?” is undecidable. The existence of the undecidable question does not render the UTM’s hardware “non-algorithmic.” The UTM simply runs, step by step. It “actualizes” the undecidable behavior through simple iteration.

Therefore, the fact that the universe contains undecidable phenomena (like the spectral gap [2]) implies only that the universe is capable of universal computation, not that it requires non-algorithmic meta-laws.

CONSTRUCTIVE COUNTER-EXAMPLE: THE RULE 110 UNIVERSE

To demonstrate this rigorously, we construct a toy TOE, $\mathcal{F}_{QG}^{toy}$, which satisfies all conditions of an algorithmic theory but exhibits the undecidability Faizal et al. claim is impossible.

Fundamental Laws

Our universe consists of a 1D grid of bits evolving under Wolfram’s Rule 110 [3]. The “Physics” is given by the transition function δ :

$$s_i^{t+1} = \delta(s_{i-1}^t, s_i^t, s_{i+1}^t) \quad (1)$$

The Python implementation below defines the *entirety* of the physical laws of this universe.

```

1 def rule110_update(current_state):
2     """
3     Input: List of bits [0, 1, 1, 0...]
4     Output: Next state
5     Physics is purely local and algorithmic.
6     """
7     next_state = []
8     padded = [0] + current_state + [0]
9     for i in range(1, len(padded)-1):
10        # The neighborhood pattern
11        p = (padded[i-1] << 2) | (padded[i] <<
12        1) | padded[i+1]
13        # Rule 110 logic: 01101110
14        is_alive = (110 >> p) & 1
15        next_state.append(is_alive)
16    return next_state

```

Listing 1. The Complete Physical Laws of $\mathcal{F}_{QG}^{toy}$

This function is finite, recursive, and deterministic. Thus, this universe is explicitly a simulation.

Emergent Undecidability

Rule 110 is proven to be Turing Complete [4]. Therefore, we can embed a Turing Machine M and an input w into the initial conditions (the “Big Bang”) of this universe. Let H be the proposition: “Does the pattern corresponding to the halting state of M appear in the grid at any time t ?”

This proposition H is:

1. **Physically meaningful:** It asks about the configuration of matter in spacetime.
2. **Undecidable:** No algorithm can determine the truth value of H for all initial conditions (due to the Halting Problem).
3. **True or False:** In any specific realization, the machine either halts or it doesn’t.

Faizal et al. would argue that because H is undecidable, the time evolution cannot be algorithmic. But we *defined* the time evolution algorithmically in Listing 1. The undecidability arises *from* the algorithm, it does not negate it.

THE TARSKI OBSTRUCTION AND “TRUTH”

Faizal et al. invoke Tarski’s theorem to state that a theory cannot define its own truth predicate, necessitating an external “Truth” ($T(x)$) provided by a meta-theory.

In our $\mathcal{F}_{QG}^{toy}$, the “Truth” of whether the system halts is not defined by a formula within the initial state. It is defined by the *execution* of the system. The universe

itself is the computer that verifies the truth. As creating a “Meta-Theory” implies adding axioms to prove the unprovable, one merely shifts the Gödel boundary. The physical universe does not need to *prove* it will halt; it merely halts (or doesn’t).

THE OBSERVER ARGUMENT (REFUTING LUCAS-PENROSE)

The original paper relies on the Lucas-Penrose argument [5], suggesting that human understanding is non-algorithmic because humans can “see” the truth of Gödel sentences that formal systems cannot prove.

This argument makes a map-territory confusion. Even if we grant (controversially) that human cognition involves non-computable quantum collapses, this applies to the *observer*, not the fundamental laws of motion.

- If the laws of physics are algorithmic (like Rule 110), undecidable states will exist.
- An observer within that universe might claim to “intuit” the outcome.
- Whether the observer is right or wrong, the *substrate* (the Rule 110 grid) continues to evolve algorithmically.

The presence of a “smart” observer does not require the underlying physics to change its character from algorithmic to non-algorithmic.

CONCLUSION

Faizal et al. claim that the universe cannot be a simulation because simulations are algorithmic and physics contains undecidability. We have demonstrated that:

1. Algorithmic systems (simulations) *naturally* generate undecidable phenomena.
2. Physical laws can be strictly computable while physical outcomes remain logically undecidable.
3. No non-algorithmic “Meta-Theory” is required to account for physical reality; the computation of the universe itself suffices.

Consequently, the claim that the universe cannot be a simulation is logically unsound. The universe may effectively be a computation evaluating its own future—a process that no shorter algorithm can predict, but which is nonetheless strictly algorithmic.

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